

CLAIMS

We claim:

1. A method of examining a structure formed on a semiconductor wafer, the method comprising:
 - obtaining a first diffraction signal measured using an metrology device;
 - obtaining a second diffraction signal generated using a machine learning system,
 - wherein the machine learning system receives as an input one or more parameters that characterize a profile of the structure to generate the second diffraction signal;
 - comparing the first and second diffraction signals; and
 - when the first and second diffraction signals match within a matching criterion, determining a feature of the structure based on the one or more parameters or the profile used by the machine learning system to generate the second diffraction signal.
2. The method of claim 1, further comprising:
 - prior to generating the second diffraction signal, training the machine learning system using a set of training input data and a set of training output data,
 - wherein each of the training input data is a profile of the structure characterized by one or more parameters, and
 - wherein each of the training output data is a diffraction signal corresponding to the profile of the structure.
3. The method of claim 2, further comprising:
 - selecting the set of training input data from a range of profiles of the structure.
4. The method of claim 3, further comprising:
 - dividing the range of profiles into a first partition and at least a second partition,
 - wherein a first machine learning system is configured and trained for the first partition, and a second machine learning system is configured and trained for the second partition.

5. The method of claim 2, wherein the set of training output data is generated based on the set of training input data using a modeling technique prior to training the machine learning system.
6. The method of claim 5, wherein the modeling technique includes rigorous coupled wave analysis, integral method, Fresnel method, finite analysis, or modal analysis.
7. The method of claim 2, wherein the training output data includes a plurality of dimensions, and further comprising:
 - transforming the training output data using principal component analysis.
8. The method of claim 7, further comprising:
 - dividing the dimensions of the training output data into a first partition and at least a second partition,
 - wherein a first machine learning system is configured and trained for the first partition, and a second machine learning system is configured and trained for the second partition.
9. The method of claim 2, wherein training comprises:
 - (a) obtaining a training input data;
 - (b) generating a diffraction signal with the machine learning system using the training input data;
 - (c) comparing the diffraction signal with the training output data corresponding to the training input data used to generate the diffraction signal;
 - (d) when the diffraction signal and the training output data do not match within a matching criterion, repeating (b) and (c) with another training input data.
10. The method of claim 2, wherein training comprises using a back-propagation, radial basis network, support vector, or kernel regression algorithm.

11. The method of claim 1, wherein when the first and second diffraction signals do not match within the matching criterion, comparing the first diffraction signal with another diffraction signal from a library of diffraction signals, and wherein the diffraction signals in the library of diffraction signals were generated using the machine learning system.
12. The method of claim 1, wherein when the first and second diffraction signals do not match within the matching criterion, generating another diffraction signal using the machine learning system to compare to the first diffraction signal.
13. The method of claim 1, wherein the metrology device is an ellipsometer, reflectometer, atomic force microscope, or scanning electron microscope.
14. The method of claim 1, wherein the one or more parameters includes one or more of critical dimension measurements, angle of incidence, n and k values, or pitch.
15. The method of claim 1, wherein the machine learning system is a neural network.
16. A computer-readable storage medium containing computer executable instructions for causing a computer to examine a structure formed on a semiconductor wafer, comprising instructions for:
 - obtaining a first diffraction signal measured using an metrology device;
 - obtaining a second diffraction signal generated using a machine learning system,
 - wherein the machine learning system receives as an input one or more parameters that characterize a profile of the structure to generate the second diffraction signal;
 - comparing the first and second diffraction signals; and
 - when the first and second diffraction signals match within a matching criterion, determining a feature of the structure based on the one or more parameters of the profile used by the machine learning system to generate the second diffraction signal.

17. The computer-readable storage medium of claim 16, further comprising instructions for:

prior to generating the second diffraction signal, training the machine learning system using a set of training input data and a set of training output data,

wherein each of the training input data is a profile of the structure characterized by one or more parameters, and

wherein each of the training output data is a diffraction signal corresponding to the profile of the structure.

18. The computer-readable storage medium of claim 17, wherein the set of training output data is generated based on the set of training input data using a modeling technique prior to training the machine learning system.

19. The computer-readable storage medium of claim 17, wherein training comprises:

(a) obtaining a training input data;

(b) generating a diffraction signal with the machine learning system using the training input data;

(c) comparing the diffraction signal with the training output data corresponding to the training input data used to generate the diffraction signal;

(d) when the diffraction signal and the training output data do not match within a matching criterion, repeating (b) and (c) with another training input data.

20. The computer-readable storage medium of claim 16, wherein when the first and second diffraction signals do not match within the matching criterion, comparing the first diffraction signal with another diffraction signal from a library of diffraction signals, and wherein the diffraction signals in the library of diffraction signals were generated using the machine learning system.

21. The computer-readable storage medium of claim 16, wherein when the first and second diffraction signals do not match within the matching criterion, generating another

diffraction signal using the machine learning system to compare to the first diffraction signal.

22. A system to examine a structure formed on a semiconductor wafer, the system comprising:

- an metrology device configured to measure a first diffraction signal from the structure;

- a machine learning system configured to generate a second diffraction signal, wherein the machine learning system receives as an input one or more parameters that characterize a profile of the structure to generate the second diffraction signal; and

- a processor configured to compare the first and second diffraction signals, wherein when the first and second diffraction signals match within a matching criterion, a feature of the structure is determined based on the one or more parameters or the profile used by the machine learning system to generate the second diffraction signal.

23. The system of claim 22, wherein prior to generating the second diffraction signal, the machine learning system is trained using a set of training input data and a set of training output data,

- wherein each of the training input data is a profile of the structure characterized by one or more parameters, and

- wherein each of the training output data is a diffraction signal corresponding to the profile of the structure.

24. The system of claim 23, wherein the set of training input data is selected from a range of profiles of the structure.

25. The system of claim 24, wherein the range of profiles is divided into a first partition and at least a second partition, and the machine learning system comprises:

- a first machine learning system configured and trained for the first partition; and

a second machine learning system configured and trained for the second partition.

26. The system of claim 23, wherein the training output data includes a plurality of dimensions, and the dimensions of the training output data is divided into a first partition and at least a second partition, and wherein the machine learning system comprises:

a first machine learning system configured and trained for the first partition; and
a second machine learning system configured and trained for the second partition.

27. The system of claim 22, further comprising:

a library of diffraction signals, wherein the diffraction signals in the library were generated using the machine learning system,

wherein when the first and second diffraction signals do not match within the matching criterion, the first diffraction signal is compared with another diffraction signal from the library of diffraction signals.

28. The system of claim 22, wherein when the first and second diffraction signals do not match within the matching criterion, the machine learning system generates another diffraction signal to compare to the first diffraction signal.

29. The system of claim 22, further comprising:

a semiconductor fabrication unit coupled to the processor, the semiconductor fabrication unit configured to perform one or more fabrication steps.